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GB 2143323 A GB 1509180 A GB 1442802 A

(58) Field of search
UK CL (Edition J) G1D DH31A
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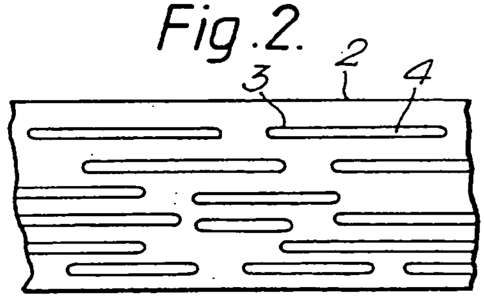
(54) Surface temperature mapping using liquid crystal materials

(57) Surface temperature is measured using a nematic liquid crystal material (4) contained within elongated open pores (3) in a stretched plastics material layer (2) mounted on the surface being measured. Polarisers are arranged either side of the layer with their optical axis at a non-zero angle to the length of the pores. These polarisers may be in contact with or spaced from the plastic layer. The liquid crystal material is arranged to have a nematic to isotropic phase transition just above the temperatures to be measured. Just below this phase transition temperature the order parameter of the nematic liquid crystal material changes by large amounts. This is observed as a large change in colour due to the changes in optical retardation. Different nematic liquid crystal material compositions may be arranged in different areas of the plastics material layer to measure a wide temperature range. Small amounts, e.g. 1 to 10% of dichroic dye may be added to the liquid crystal material; in this case one polariser may be dispensed with. A reflector may be arranged on the surface to be measured and the temperature measued by reflected light. The device may be applied to a wind tunnel aircraft model to provide surface temperature profiles. The model may be of transparent plastics material.

Fig.2.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

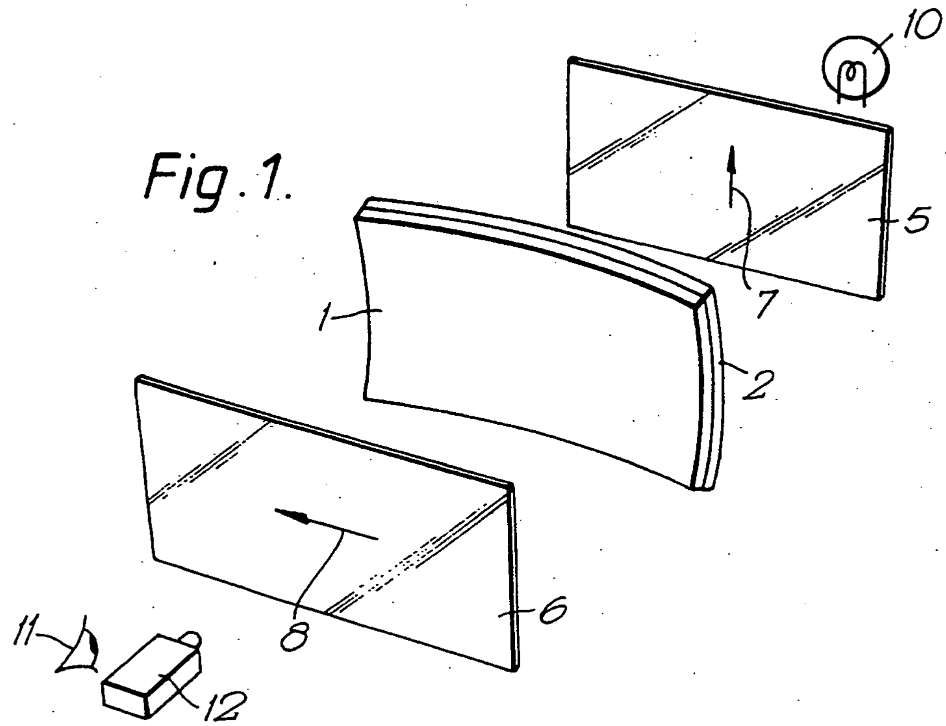


Fig.2.

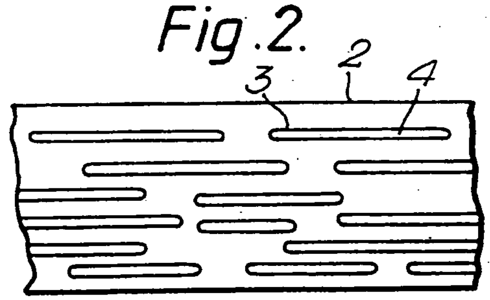
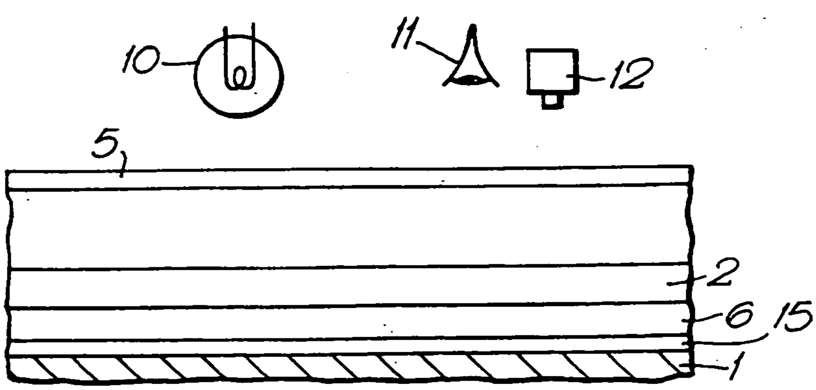


Fig.3.



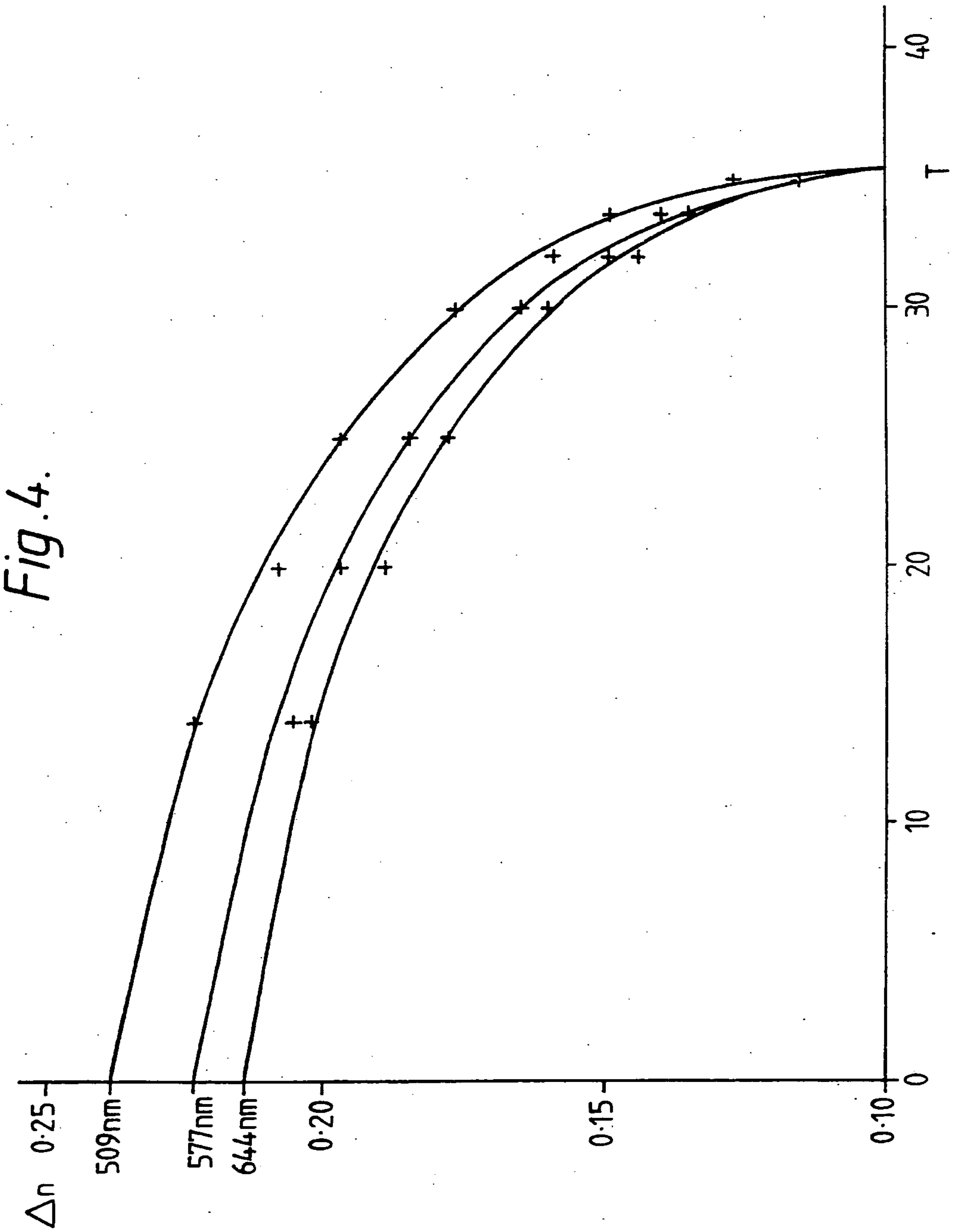


Fig. 4.

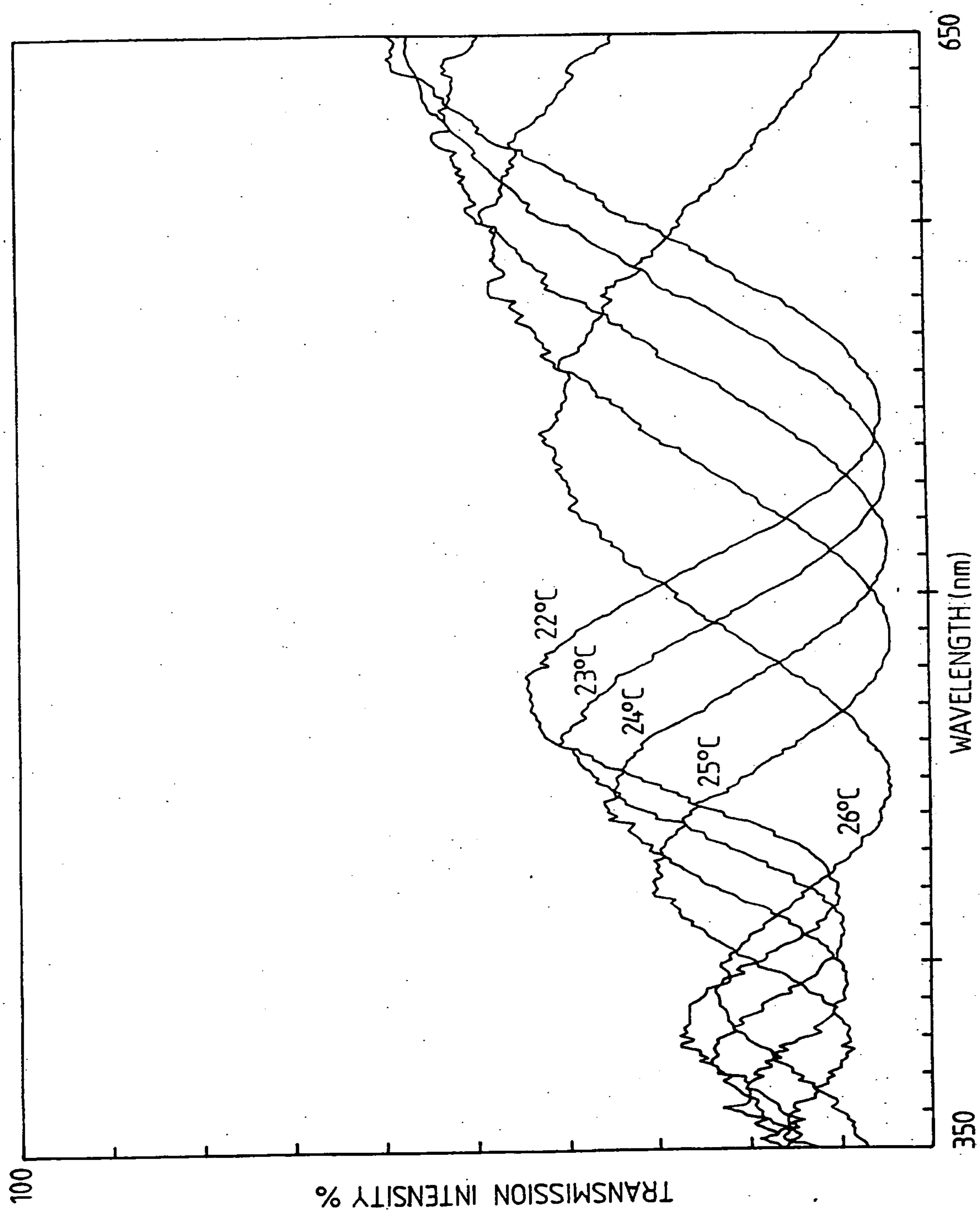

22°C
23°C
24°C
25°C
26°C
WAVELENGTH (nm)
350
650
100
TRANSMISSION INTENSITY %

Fig.5.

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SURFACE TEMPERATURE MAPPING USING LIQUID CRYSTAL MATERIALS

This invention relates to surface temperature mapping using liquid crystal materials.

The application of liquid crystals as thermal transducers in aerodynamic testing is rapidly developing as an important technique for surface temperature visualisation and measurement. Micro-encapsulated thermochromic liquid crystals have been sucessfully used to determine heat transfer co-eficients up to 1000 $Wm^{-2}\,{}^{\circ}K^{-1}$; see for example J. Phys. E Sci. Instrum. 20 (1987) 1195-1199, article by P. T. Ireland and T. V. Jones.

Thermochromic liquid crystal materials are cholesteric liquid crystal materials having a cholesteric pitch around the wavelength of light. This pitch selectively reflects light, i.e. Bragg-like reflection, the observed colour being dependent on the pitch. The material is designed to change its pitch with temperature over a range of operating temperatures so that different colours are observed for each temperature. Such thermochromic materials can be micro encapsulated and held in a PVA binder which is then coated onto surfaces. Examples include thermometers and the mapping of skin temperatures.

The above heat transfer co-efficient limit is imposed by the helical response time and the pitch gradient which arises because of the thermal gradient across the liquid crystal layer.

The present invention has the object of extending the range of heat transfer co-efficients accessible by a surface thermographic technique.

According to this invention a liquid crystal device for use in surface temperature mapping comprises a sheet of plastic material having an elongated open pore structure into which liquid crystal is absorbed, characterised in that the liquid crystal material is a nematic liquid crystal material having a nematic to isotropic phase change just above the device operating temperature range.

According to this invention apparatus for mapping surface temperature comprises:-

a layer of liquid crystal material in intimate thermal contact with a surface to be mapped,

means for illuminating the liquid crystal layer,

means for detecting the colour changes of the liquid crystal layer with temperature,

characterised by

a sheet of a plastics material having an elongated open pore structure,

a layer of a nematic liquid crystal material in the elongated pores, the nematic material having a nematic to isotropic phase transition just above the range of temperatures to be measured, and

two polarisers co-operating with the liquid crystal layer to indicate temperature changes.

The nematic/isotropic phase transition may be about 1 to 5°C above the highest temperature to be measured. Preferably this is as close to the highest temperature as possible, eg 0.1°C. Should a temperature be above this transition temperature its value is indeterminant.

The two polarisers may be two polarising plates arranged either side of the liquid crystal layer, or a single polariser plate and an amount of a dichroic dye in the nematic liquid crystal material.

The strip of plastics material may be the material Celgard 2500 (T.M.). It is known from GB 1,509,180 to introduce nematic liquid crystal material into the pores of Celgard (T.M.). Dyes may be incorporated into the nematic material. This gives a highly aligned layer of nematic liquid crystal material which may be used as a coloured polariser. A sheet of Celgard (T.M.) with nematic material is birefringent. It may be placed between two neutral polarisers with the aligned direction at 45° to the polarising axes of the polarisers to provide a colour. Moving the filled Celgard sheet to angles other than 45° gives different colour; zero and 90° gives no colour.

Heating the nematic material into the isotropic phase reduces its order parameter to zero. A typical order parameter is around 0.7 and is a measure of how closely the pleochroic molecules co-operatively orientate in a single direction in the aligned nematic phase. Just below the nematic to isotropic phase transition there is a large change in the order parameter. This change is very rapid; much quicker than the helical response time. This allows very fast temperature changes to be observed on a heated surface.

The invention will now be described by way of example only with reference to the accompanying drawings of which:-

Figure 1 is a view of apparatus for measuring surface temperatures;

Figure 2 is a plan view of a layer of stretched plastics material used in Figure 1;

Figure 3 is a view of an alternative to Figure 1 operating on reflected light;

Figure 4 is a graph of birefringence against temperature for one particular nematic material;

Figure 5 is a graph of transmission intensity against wavelength.

As seen in Figure 1 a transparent Perspex (T.M.) article to be mapped 1 is covered with a nematic liquid crystal carrying sheet 2 shown more clearly in Figure 2. Optically isotropic glue such as Jon Cryll 80 (T.M.) may be used to secure the sheet 2 into intimate thermal contact with the article 1. Alternatively the surface may be cleaned and the sheet 2 pressed onto the surface 1 to exclude trapped air. The sheet 2 is then held by air pressure.

This sheet 2 has an elongated open pore structure 3 into which nematic liquid crystal material 4 has been drawn by capillary action. A typical pore is a few μm wide and 30 to 100 μm long. It is quite dry to the touch, but can be coated with a thin protective layer if required.

The article shown 1 would normally be a part of a much larger article such as a model of an aircraft.

Either side of the article 1 are neutral polarisers 5, 6. arranged with their polarisation axis 7, 8 crossed and at 45° to alignment 9 of the layer 2. Light from a lamp 10 is directed through the combination of polariser 5, layer 2, article 1 polariser 6 (acting as an analyser) to a detector such as an observer 11 or camera 12.

The article is typically arranged in a wind tunnel for measurement of the temperature changes with flow over a shaped article such as one representing part of a wing. The polarisers 5, 6 may be located in the walls of the wind tunnel, not shown. Alternatively they may be arranged in contact with the layer 2 and article 1. However, this may affect temperature gradients in an undesired manner for some experiments.

A single nematic mixture may be introduced into the sheet. Alternatively to cover a wider temperature range, different mixtures may be introduced into different areas of the sheet; each area having a nematic with a different N - I transition. A range of sheets 1 may be prepared each with a different nematic mixture and hence useful over a different temperature range.

A dye may be added to the nematic liquid crystal material is typically 0.1 to 10% by weight. Suitable dyes are high order parameter dyes, e.g. anthraquinone dye; see F. C. Saunders et al, I.E.E.E. Trans. Electron Devices, Vol. E.D30 No. 5 (May 1983) pp 499. Examples are manufactured by BDH Chemicals Ltd., Poole, England under catalogue numbers D80 (yellow), D101 (orange), D81 (red), D82 and D102 (blue) used single or in combination.

When a dye is incorporated into the liquid crystal material it acts as a coloured polariser. Thus one of the polarisers, 5 or 6, may be dispensed with.

In operation an air flow over the article 1 causes a rise in temperature which varies across its surface. The variation in surface temperature causes a similar temperature variation in the liquid crystal layer 4. This results in a very localised change in the liquid crystal order parameter and a consequential change in optical retardation. This is observed as a localised change in colour. The change in order parameter is reversible with temperature changes. Reducing the temperature increases the order parameter, increasing temperatures reduces the order parameter.

The nematic liquid material may be the BDH (British Drug Houses, Poole, Dorset, England) material reference K15 which is 4-n-pentyl 4'-cyanobiphenyl. The variation of birefringence with temperature is shown in Figure 4, the nematic/isotropic phase transition Tr is at 35.4°C. Just below Tr the birefringence, and hence order parameter, changes considerably more per degree than at lower temperatures. The three curves represent measurements at 509 nm upper curve; 577 nm middle curve; and 644 nm lower curve. This material is useful in mapping temperatures around 28 to 34°C. Different materials are selected to give Tr values just above the range of temperatures to be mapped. Tables produced by liquid crystal manufacturers give Tr values for their different materials. Examples of BDH materials are given below in Table 1.

Figure 5 shows how the intensity of transmission of Celgard 2500 with K15 varies with wavelength for temperatures of 22, 23, 24, 25, and 26 C.

The surface temperature of an opaque article may be measured using reflected light. This is shown in Figure 3. A reflecting layer 15 is glued to or sprayed on the surface of the article 1. Alternatively, for metallic surfaces the surface may be polished to provide a reflector. On top of this is the polariser 6 followed by the layer 2 of Celgard 2500 incorporating K15 nematic liquid crystal material. A further polariser 5 may be in contact with or placed a distance away from the sheet 2. As before the article 1 is illuminated by a lamp 10 and observed at 11, 12.

Table 1

Eutectic	N-I °C
E1	38.3
E2	45.8
E3	55
E4	60.7
E5	50.5
E7	60.5
E8	72
E9	83.5
E12	59
E18	60
E24LV	54.5
E25M	62
E26M	62

Claims

1. A liquid crystal device for measuring the temperature of a suface comprising:-

a layer of a plastics material having of an aligned and elongated open pore structure,

a nematic liquid crystal material having a nematic to isotropic phase transition just above a range of temperatures to be measured, the nematic material being retained and aligned in the open pores,

a polarising sheet in contact with one side of the plastic material with the optical axis of the polarising sheet at a non zero angle to the alignment of the pores in the plastics material, and

either a second polariser in contact with the other side of the plastic material, or an amount of a dichroic dye in the nematic liquid crystal material,

the device being constructed for attachment to the surface to be measured.

2. The device of claim 1 and further including a reflecting surface arranged to reflect light back through the device.

3. The device of claim 2 wherein the polariser between the reflector and nematic material is replaced by a quarter wave plate.

4. The device of claim 1 wherein a single nematic liquid crystal material composition is incorporated into the sheet of plastics material.

5. The device of claim 1 wherein different areas of the layer of plastics material contain different nematic liquid crystal material compositions each with a different nematic to isotropic phase transition temperature.

6. The device of claim 5 wherein a different dye is added to the nematic liquid crystal material in the different areas.

7. Apparatus for mapping surface temperature comprising:-

a layer of liquid crystal material in intimate thermal contact with a surface to be mapped,

means for illuminating the liquid crystal layer,

means for detecting the colour changes of the liquid crystal layer with temperature,

characterised by

a sheet of a plastics material having an elongated open pore structure,

a layer of a nematic liquid crystal material in the elongated pores, the nematic material having a nematic to isotropic phase transition just above the range of temperatures to be measured, and

two polarisers co-operating with the liquid crystal layer to indicate temperature changes.

8. The apparatus of claim 7 wherein the two polarisers are two polarising plates arranged either side of the liquid crystal layer.

9. The apparatus of claim 7 wherein the two polarisers are a polarising plate and an amount of dichroic dye incorporated in the liquid crystal material.

10. The apparatus of claim 7 and further comprising a reflector between the surface to be mapped and the liquid crystal material.

11. The apparatus of claim 7 wherein one or both polarisers are spaced apart from the sheet of plastic material.

12. The apparatus of claim 7 wherein one or both polarisers are in contact with the sheet of plastic material.

13. A method of measuring surface temperatures comprising the steps of

arranging a sheet of a plastics material on a surface to be measured, the plastics material having a structure comprising elongated open pores containing and aligning a nematic liquid crystal material with a nematic to isotropic phase transition just above the range of temperatures to be measured,

illuminating the nematic material with plane polarised light,

receiving plane polarised light from the nematic material,

the arrangement being such that different temperatures of the surface are observed as different colours of the liquid crystal material.

14. A method, apparatus, and a device for measuring the temperature of a surface, constructed arranged and adapted to operate substantially as hereinbefore described with reference to the accompanying drawings.

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